Develop a Hybrid Coordinate Ocean Model with Data Assimilation Capabilities

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Award #: N00014-00-F-0025

http://www.rsmas.miami.edu/groups/micom.html

LONG-TERM GOALS

To develop data-assimilating capability for HYCOM, the hybrid version of University of Miami's Isopycnic Coordinate Ocean Model. This project is one component of the NOPP consortium for developing a data-assimilating ocean model based on a hybrid vertical coordinate. The focus of this component has been on the assimilation of in situ hydrographic data to correct the model state.

OBJECTIVES

a) To develop a methodology for assimilating temperature profiles from XBTs that accommodates the peculiarities of the hybrid system of vertical coordinates, allowing density to be corrected at fixed pressure levels where the coordinate is pressure-like, allowing interface pressures to be corrected when the coordinate is density-like, and allowing both to be corrected in the transition zone.

b) To compare the model-state to observations and to infer error statistics and influence functions.

c) To develop codes for implementing this methodology.

APPROACH

Companion salinity profiles are to be estimated and used to estimate density profiles from which data for layer-interface pressures and layer potential-densities can be obtained. At first, error-statistics, which govern the nature of the data-based corrections to the model state, are to be postulated so that assimilation codes can be made functional; later, they are to be based on model-data comparisons. The method is to be sufficiently flexible to allow for incorporation of other types of data, in particular those from satellite-based observations.

WORK COMPLETED

a) The design for the data-assimilation methodology exists and is being tested.

b) The preprocessing system to estimate companion profiles and layer/interface values has been implemented. Additional software engineering is needed, and possible improvements and enhancements have been identified.

c) Initial efforts have been made toward developing procedures for comparing model to data and inferring influence functions from error statistics.

d) Atlantic XBT data for a twenty-year reanalysis have been assembled with casts exhibiting unreasonable behavior discarded.

e) A paper describing the methodology is under review for publication and another is in preparation.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE **Develop a Hybrid Coordinate Ocean Model with Data Assimilation Capabilities**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Atlantic Oceanographic and Meteorological Laboratory,,4301 Rickenbacker Causeway,Miami,,FL, 33149**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

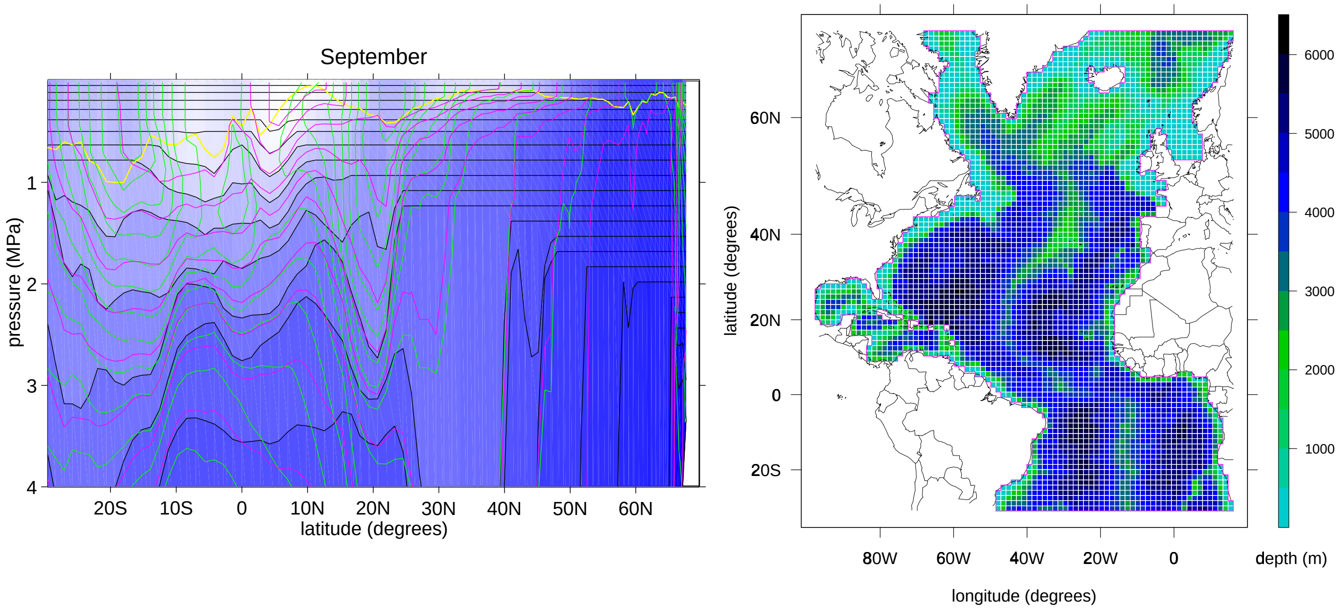

Figure 1: Left: Upper 400 meters along 31°W for 1972 from the Atlantic 1.4° HYCOM model without data assimilation. Shade of blue indicates potential density; black curves, interface pressure; magenta, potential temperature (2°C spacing); green, salinity (0.2 psu spacing); yellow, bottom of the mixed layer. Right: Mercator projection of grid with map overlay and with colors indicating depth.

RESULTS

HYCOM has layers that are density-like (specified potential density) at depths where the ocean is stratified and pressure-like (specified thickness) where it is well mixed, smoothly changing from one aspect to the other (left panel, figure 1); the Atlantic model with 1.4-degree resolution (right panel, figure 1) provides the context for development. The seasonal cycle of the mixed layer and upper thermocline requires that the nature of the layers change both with time and with location. While this formulation offers advantages for modeling, it also imposes challenges for data assimilation. We must determine the nature of the layers from data in order to know how the model state needs to be corrected.

The focus of this sub-project has been on the use of XBT data, because they comprise the bulk of the in situ data and because they provide the most direct information about the vertical structure of the ocean and thus about the nature of the hybrid layers. The design that has been developed addresses this issue directly. The XBT data are from AOML's Global Ocean Observing System (GOOS) Center (left panel, figure 2). The ultimate goal is to use all types of data, combining the horizontal information provided by satellite-based observations with the information about vertical structure from in situ soundings.

Unfortunately, density is not directly observed, nor is salinity, which together with temperature determines density. To infer where layer interfaces should be, a salinity strategy is necessary. Some method is needed to estimate companion salinity profiles for the XBT data. For expediency, so that other aspects of the project can progress, salinity is being estimated from the climatological mean conditions for the location and time of year. Better estimates are achievable (Hansen and Thacker, 1999) but to do so would require a separate project.

The methodology for pre-processing XBT data is illustrated in the right panel of figure 2. For each XBT cast climatological salinity is interpolated to depths where temperature is measured, and the equation of state of sea water is then used to estimate potential density and potential temperature at these depths. The identification of the positions of layer interfaces (horizontal steps) is based on the target potential densities of the layers. Starting from the top, as long as water is heaver than a target value, minimum

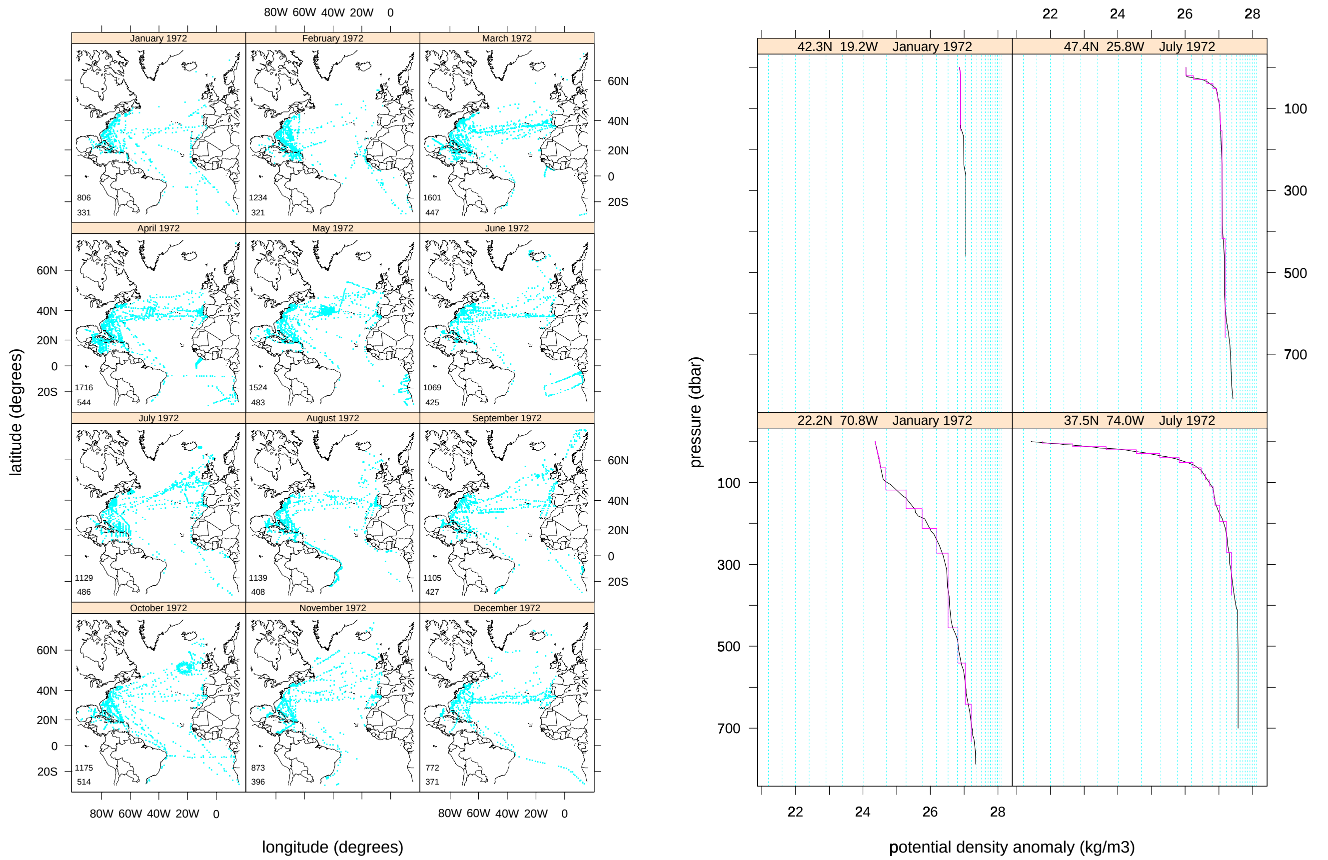

Figure 2: Left: Cyan dots mark locations of XBT casts for the year 1972. The numbers in the southwest corner of each panel indicate casts (upper) available for assimilation and cells (lower) sampled. Right: Potential density (black) as estimated from observed temperature profiles and local monthly mean salinity profiles and (magenta) after preprocessing to determine model layer thicknesses and interfaces. The cyan lines indicate target values for the model layers.

layer thickness is specified. Once water is encountered that is sufficiently dense, layers with their target densities are assigned appropriate thicknesses. Finally, layer values are evaluated as integrals from one interface to the next. This produces “observed” values of the model layer’s potential temperature and potential density and for the pressure at the interfaces separating them.

The XBT data that are being used for have undergone extensive quality control by AOML’S GOOS Center and by Canada’s Marine Environmental Data Service (MEDS). Flags were used to mark suspicious data. The bulk of the data were examined by both groups; of these, only those deemed good by both were accepted. From the remaining data, only those that were examined by one of the two groups and found to be acceptable were used; those that had undergone no quality control were not used. In spite of the careful screening by these two groups, some of the data selected on the basis of the flags were found to have problems. Casts that had unphysically hot or cold temperatures were discarded. In addition, seeming good data that differ by more than three standard deviations from the climatological mean were excluded. At this point it is still impossible to say whether some discarded casts should have been retained or whether some retained casts should be discarded. To do so would require considerable additional effort, and the care already taken to assemble a reliable set of data has consumed more time than had been anticipated. A separate project is needed to study the distribution of

data in order to determine which of the data really should be assimilated and which should be excluded. Similar work is needed to assemble usable XBT data for the entire world ocean.

The data within the domain of the 1.4° Atlantic HYCOM domain (30S to 70N) have been pre-processed to give model-relevant values: depths and thicknesses of the model's layers and layer-averaged potential densities and potential temperatures. A variety of techniques (see, for example, Malanotte-Rizzoli, 1996), most of which are based on the error statistics of the model state, can be used to assimilate the data. The approach taken here is to maintain flexibility, using simple, easy to implement methods in the beginning while allowing for increasing sophistication in the future. Codes implementing sequential optimal interpolation have been prepared to assimilate these data at monthly intervals, as the objective is to provide a model-based analysis of the month-to-month evolution of the state of the ocean. Because early simulations have focused more on getting the hybrid model working than on model-data comparisons, details of the error covariances are not yet suited to inferring influence functions for spreading the corrections away from the observations. As the project progresses, more emphasis will be placed on the statistical basis of the corrections. The immediate need is to assess the impact of the corrections on the model state and to determine whether any alterations are needed in the design concept.

IMPACT/APPLICATIONS

This research should lead to a facility for producing model-based analyses of hydrographic data. Low-resolution analyses can be used to provide initial conditions for high-resolution models and for studying climate. At high resolution, this approach can be extended to incorporate detailed horizontal information provided by satellite-based observations.

TRANSITIONS

The assimilation codes that are under development will be made available to the wider oceanographic community as a part of the HYCOM modeling facility.

RELATED PROJECTS

This project is one component of the NOPP consortium for developing a data-assimilating ocean model based on a hybrid vertical coordinate.

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